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Surveys of Soviet-Bloc Scientific and Technical Literature

DATA ON SOVIET SPACE PROGRAM

Analytical Survey

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FOREWORD

This is the fifth in a series of reports published in response to Work Assignment No. 57. It contains a selection of Soviet technical papers and attempts to give a view of some space-exploration problems as they existed at the end of 1964. The problems which are treated here are divided into four sections as follows: I) Soviet Research in Space Biology; II) Supersonic and Hypersonic Aircraft; III) The Voskhod Spacecraft; and IV) Soviet Exploration of the Moon. The materials from which this report was compiled are available at the Aerospace Technology Division of the Library of Congress. Numbers in brackets within the text refer to the references listed at the end of the report.

SECTION I. SOVIET RESEARCH IN SPACE BIOLOGY

At the Fifteenth Congress of the International Astronautical Federation, held in Warsaw in September 1964, the problems most widely discussed concerned the role of man in spacecraft guidance, the mechanics of low-thrust space flight, and space medicine. Following is a review of three reports presented at this congress by Soviet scientists and published in the November 1964 issue of the Soviet Air Force periodical, *Aviatsiya i kosmonavtika*.

Research on human adaptability to space environments was conducted by subjecting human beings to spacecraft-like conditions for as long as 120 days [1]. The atmosphere which develops in a sealed space chamber occupied by man and the behavior of man under such conditions were investigated, as well as the effects of such phenomena as ionizing radiation in small doses, periodic temperature increases, and noise.

The experiments suggest that although human subjects show a remarkable ability to adapt to the conditions existing in a sealed chamber, this adaptation seems to be only temporary. Continued exposure of the human organism to these conditions eventually leads to the disruption of the adaptation mechanisms and the development of an asthenic syndrome, as evidenced by reduced work efficiency, general fatigue, change in sleeping patterns, weakened immunoreaction, reduced functional potentialities of the cardiovascular system, and specific changes in the dynamics of cortical processes. It is noted that the balance of the nervous processes is disrupted in the cerebral cortex long before the symptoms of asthenia become fully evident.

Of special interest are the changes which man undergoes when he leaves the test chamber and returns to normal life. These changes, called "emergence reactions," are primarily a deepened asthenic state which tends to persist.

No specific changes were observed in such functions as nervous-system activity, blood circulation, respiration, and metabolism. When human subjects were exposed to the effects of increased temperature (40—47°C), intense noise, and ionizing radiation, the secretion of amino compounds increased by approximately 80%.

The most important psychological effects displayed by a man placed in solitary confinement are due to his forced isolation from the outside world, unusual surroundings, and the monotony of his habitat, the incoming stimuli having been reduced to a minimum. These psychological factors are largely responsible for the physical changes mentioned earlier.

An article, "Under prolonged space-flight conditions," [2], states that following the successful execution of space flights lasting for several days, the rapidly advancing science of astronautics has established the realization of distant and prolonged flights as its next goal. Inter-

planetary flight will differ from orbital flight not only with respect to navigation technique, but also with respect to the conditions surrounding the life and the activity of man.

The communications media and equipment which will be used in gathering and processing physiological data during prolonged space flight include direct and indirect telemetry, radio and telegraphic communications, simplex and duplex space television, memory devices, and special electronic computers. Automatic information-processing methods used aboard spacecraft will ensure a definite operating schedule for evaluating the situation and transmitting the code through channels with limited capacity.

Fig. 1 [3] shows the design concept of a physiological-measuring system which can be used aboard a spaceship. Here, (A) denotes the astronaut who is continuously wearing electrodes, pickups, and instruments which relay data over wire or radio channels to the medical-checkup unit (MC) and from these to the special computer (SC). From those pickups and electrodes which are applied to the astronaut periodically (once or twice per day), information is sent through wire channels to the medical research unit (MR), as well as to the special computer (SC). The information thus processed is now transmitted to a registration chart (not shown on the diagram), to the memory unit (MU), and to the telemetric system (TS) either directly or through the memory unit (MU).

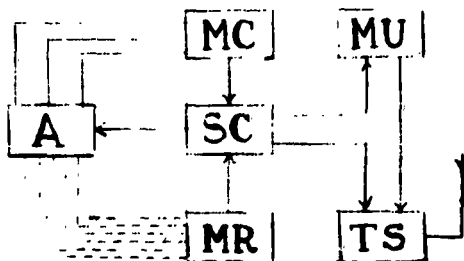


Fig. 1. Diagram of a physiological measuring system

Although the effects of weightlessness on humans has been studied for a number of years, the Soviets are still deeply concerned about the implications of this phenomenon. P. K. Isakov and others [3] emphasize the need for a theory which would treat as factors of the same category the effects of acceleration and weightlessness upon the various functions of the human body. Considering the problem of weightlessness as "extremely important both practically and theoretically in planning long-range space flights, such as a flight to the Moon where man will encounter abnormal gravity," Isakov suggests that the following aspects of the weightless condition be investigated: decreasing differential threshold of gravity perception during weightlessness; adaptability of the human organism to the state of weightlessness; the effect of acceleration and weightlessness upon bioelectric activity; vestibular nystagmus and otolithic irritation; and the effects of the body's position during a period of adaptation to changing gravitational forces.

Soviet scientists are considering ways of creating artificial gravity on future long-range spaceships in case this should prove necessary. Valuable information on this subject was obtained by evaluating the Vostok flights (especially Vostok-5, which was flown by Bykovskiy for about 119 hours). An interesting statement made at the IAF Congress was that under zero-gravity conditions certain drugs, such as tranquilizers, can have an effect on the human body opposite to that experienced under normal gravity conditions.

SECTION II. SUPERSONIC AND HYPERSONIC AIRCRAFT

A. Supersonic Aircraft

Several fixed-wing and variable-sweptwing configurations are being studied by Soviet engineers in order to correlate experimental and theoretical data and to define the aerodynamic state of the art. Other factors which will ultimately determine the optimum configuration of an SST aircraft include takeoff and landing characteristics, structural feasibility, and ease of fabrication [4].

From the standpoint of aerodynamics, writes Constantin Sabin Ioan [4], the most suitable design for a passenger aircraft flying at Mach 2.2 seems to be that of a delta-shaped "flying wing" with low aspect ratio, since it offers little resistance to forward movement at transonic speeds and at the cruising speed. It is of interest to point out that the thickness ratio (which represents the ratio of the thickness of the wing to its chord in a certain section) of such an airfoil does not exceed 3—4%.

In order to lessen the wave drag, the fuselage must conform to the "area rule." This means that its cross-sectional area must vary in such a manner that it does not change abruptly in the zone where the wing (with the engines) is attached to the fuselage.

Soviet designers prefer the classical design, with a triangular wing and tail units in the aft portion of the fuselage. The best solution for a Mach-3 passenger aircraft is said to be variable-sweep wing (one which can be changed in flight). Design difficulties connected with the construction and functioning of the mechanism for changing the sweep, however, and the impossibility of placing the fuel tanks in the moving part of the wing, have compelled designers to favor the "canard" configuration for its advantages for supersonic cruising as well as for landing.

The choice of the design, size, and high-lift and braking systems (for landing) are also influenced to a great extent by the limitations imposed upon landing speed by existing airports.

B. Hypersonic Aircraft

The range of near-Earth velocities available to piloted aircraft extends from zero speed to orbital velocity [5]. A large portion of this wide spectrum consists of hypersonic speeds not yet attained by man. The term hypersonic is generally applied to velocities greater than Mach 5. The flow pattern of the hypersonic region does not differ from the supersonic except that at very high Mach numbers the Mach angle is so small that the shock wave will be almost parallel to the direction of motion.

In an interview with the Czechoslovakian aviation journal *Kridla Vlasti*, Soviet chief designer A. I. Mikoyan stated, among other things, that "The design of a hypersonic aircraft involves thermal-barrier problems which

can be resolved by using the [phenomena of] dissociation and ionization of air to effect electromagnetic control of the flow over the aircraft's surfaces. Takeoffs and landings will be different from those of present-day supersonic aircraft. Wing flow control during flight may be very advantageous. It is possible that aircraft with ranges of several hundred thousand kilometers will be designed for research purposes. High energy fuels and high aerodynamic efficiency will further increase the operational range of hypersonic aircraft. Another possible means of increasing range and flight duration consists in the design of a propulsion system which uses oxygen accumulated during flight in the atmosphere. Attempts will be made to effect flight in the atmosphere at speeds approaching those of spacecraft, with hundred-thousand-km ranges and multiton cargoes. Such aircraft will be based at conventional terrestrial airfields [6]."

In view of missile and satellite developments, it is not certain whether there will be a requirement for a bomber or reconnaissance aircraft capable of sustained speeds over Mach 4. With such an aircraft, as with a supersonic transport, up to 50% of the fuel load may be needed for takeoff, subsonic climb, acceleration to cruising speed, descent, and reserves for use under subsonic conditions, the actual proportion depending on the range and mission. It is to be expected that strenuous efforts will be directed toward the extension of the upper speed limits of the turbine engine before resorting to the installation of separate ramjets parallel to the turbines.

Fig. 2 [5] shows the range of near-Earth flights accomplished by heavier-than-air vehicles. Hypersonic speeds are found between the 3000

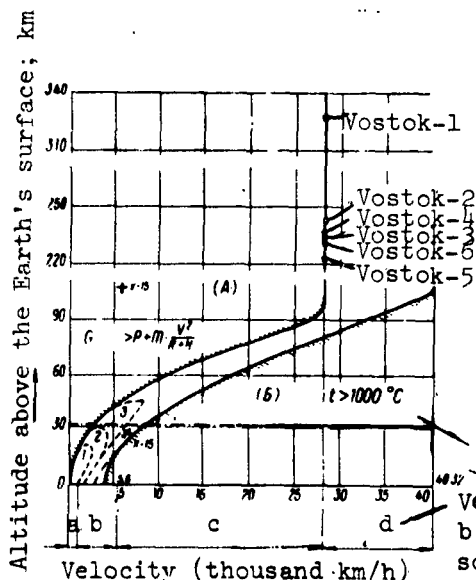


Fig. 2. Prolonged flight "corridor" for heavier-than-air craft within the range of near-Earth velocities

(A) - Limitation imposed by lift; G - weight of aircraft; P - lift; m - mass of aircraft; V - flight velocity; R - radius of the Earth; H - flight altitude; 1 - turbojet flights; 2 - ramjet flights; 3 - flights by hypersonic aircraft of the near future using hypersonic ramjet engines; (B) - limitation imposed by the maximum-permissible kinetic-heating temperature.

31 km - outer-space boundary
Velocities: a - subsonic;
b - supersonic; c - hypersonic; d - escape

and 28,400 km/hr marks. The relatively narrow "corridor" in which prolonged horizontal flights are possible encompasses the regions in which aerodynamic flights are feasible.

The upper limit of the "corridor" is the geometrical locus of points of minimum velocities at which prolonged flights are possible. This curve is a function of aircraft weight, wing area, wing span, and the available engine thrust. If the wing load is decreased, this boundary will shift toward higher altitudes; other flight characteristics of the aircraft, however, will then deteriorate.

The lower boundary of the "corridor," with the exception of its lower-left section, indicates the limits imposed upon flight velocities and altitudes by the heat barrier. This boundary is not regarded as a true ceiling, but rather as a range of altitudes below which the heat resistance of materials must be increased, heat-insulating coatings further improved, special cooling methods devised, and new designs used.

For moderate velocities and altitudes, the turbojet-powered aircraft is said to be the most economically efficient airplane. The present limitations with respect to both velocity and altitude will be extended by the ramjet engine, which will use oxygen from the surrounding atmosphere during its flight.

The idea of building a piloted hypersonic aircraft powered by ramjet engines is not far from being realized. Such an aircraft will be built essentially from aluminum alloys. With a 10% payload, it will fly a distance of 17,000 km at 30,500-m altitude in less than 5 hours (using 1 hour each for the ascent and for the letdown).

A pilotless hypersonic ramjet aircraft is said to be superior to the ballistic missile with respect to payload. Depending on the type of fuel used, the payload may account for 55—65% of the total weight of a hypersonic aircraft. At Mach 7, the flight range of hypersonic winged air-to-ground missiles powered by ramjet engines may reach 1300 km.

In an article dealing with problems associated with hypersonic flight, Yu. Popov and Yu. Pukhnachev [7] describe the configuration and flight characteristics of a projected hypersonic aircraft, referring to it as an asymmetric aircraft with "variable geometry." The aircraft consists basically of a wing with a fuselage on one side and a vertical fin on the other side, the engines being located under the central portion of the wing. The arrangement of the various components can be changed. Thus, to ensure maximum lifting power during takeoff, the engines, fuselage, and vertical fin are located perpendicular to the wing. To reduce drag in flight, the fuselage, engines, and vertical fin are adjusted to form an acute angle with the wing, remaining at the same time oriented along the direction of flight.

According to Pavlov [5], it is expected that a piloted winged supersonic aircraft powered by airbreathing jet engines will be used as a launching platform for a rocket-propelled spacecraft.

C. The Sonic Boom

In addition to the many technical problems involved in the design and manufacture of the SST, the question of how people would react to the noise of the sonic boom on a several-times-a-day basis and how much property damage such booms would cause has not yet been answered satisfactorily.

The variation in pressure caused by the shock waves that accompany the plane is transmitted to the ground in the form of a "pressure wave," which an observer on the ground perceives as a cannon boom [4]. The intensity of the sonic boom increases with the weight and speed of the aircraft, but diminishes considerably as the flight altitude is increased. When the instantaneous pressure change does not exceed 5—6 kg/m², the sonic boom resembles the sound of distant thunder and can be endured; but pressure change in excess of 10 kg/m² can break windows and even destroy flimsy buildings in localities over which the supersonic passenger planes will fly. Even if the sonic boom produced by an SST is not too strong (with an instantaneous pressure change below 7 kg/m²), it is doubtful that this aircraft will be used on air routes leading over densely populated areas.

Noise produced by the supersonic transport will be a function of the type of power plant used, the manner in which it is operated, and the configuration of the aircraft in which it is installed. Sonic-boom research indicates that there will be large penalties in gross aircraft weight unless the SST configuration is specially designed to minimize this sonic boom.

D. Soviet Officials on SST

Mr. Smirnov, a representative of the Soviet Aeroflot, stated in a talk given in London at the Society of Licensed Aircraft Engineers and Technologists that the USSR needs twenty supersonic transport planes. He explained in detail that three large groups of Soviet designers are working on this project. Their job is to come up with one or two final designs, either independently or jointly, for a Mach 2—3 transport plane which after flight tests will be put into serial production. [8].

The head of Aeroflot said on 7 July 1964 that Soviet designers were working on a supersonic airliner. He indicated that the Russians hoped to have one flying before the United States. The Official, Yevgeniy F. Loginov, said at a news conference that it was difficult to say who would be first, but added, "Apparently we will not be late." Loginov suggested that the United States might lack an airliner capable of flying nonstop from New York to Moscow with two hours' of fuel left: the Soviet TU-114 turboprop airplane, which flies from Murmansk to Havana nonstop, could make the trip, Loginov said. He added that the IL-62 was being tested for such use. This 186-seat plane has the same general design as the British VC-10 with four jet engines mounted in pairs by the tail, swept wings, and a very high horizontal tailpiece. It is expected that the IL-62 will be delivered to Aeroflot for its own tests next year [9].

In the opinion of aircraft designer A. Mikoyan, supersonic aircraft will attain speeds of Mach 6—8 in the near future. Such aircraft, which Mikoyan calls "semispace," will have several stages. The last stage will have wings, the area and shape of which can be changed to enable long-range flights at high speeds (it is assumed that such a vehicle will be able to fly nonstop around the Earth several times), as well as permit landing at lower speeds on normal airfields. To build a semispace aircraft it will be necessary to use new heat-resistant materials and to effectively solve the problems of engine cooling and heat insulation of the cabin [10].

Soviet Chief Aircraft Designer V. M. Myasishchev, expressing his views on the future of aviation, stated that before 1970 flying speeds would approach 2000 km/hr, and that within twenty years passenger transports would fly as fast as 2500—3000 km/hr. With modern aircraft requiring longer runways, Myasishchev stressed the necessity of developing STOL and VTOL aircraft. However, he emphasized that a number of complex scientific and engineering problems must first be resolved, the most urgent for supersonic aviation being the suppression of the damaging effect of shock waves. In Myasishchev's opinion, rocketry will not replace aviation because each has an advantage over the other under certain conditions. He further stated that the two were developing together and would complement one another, giving as an example the short-takeoff supersonic jet fighter using rocket engines which was demonstrated at the air parade on 9 July 1961. According to Myasishchev, rocket aircraft will be used to transport mail, cargo, and passengers [11].

Professor B. G. Shpital'nyy, Stalin Prize Winner and Hero of Socialist Labor, speaking of future problems in aviation, advocated the development of VTOL aircraft and the design of powerful engines for them. He stated that "our" small group of physicists and mechanics, working on a voluntary basis, is engaged in experimental physics and is striving to contribute to the design of plasma engines [12].

The famous airplane designer Antonov, in an interview with the Soviet news agency TASS, voiced his opinions regarding the future development of civil aviation [13]: Hypersonic planes will service air routes of 3000 to 4000 km or more. The speed over medium distances will be held to 2500 to 3500 km/hr. On long-distance flights, the speed will reach 5000—7000 km/hr. Future hypersonic planes will have triangular wings and elongated fuselages. The engines will most probably be located in the stern of the plane to minimize frontal drag and noise.

In another interview with a TASS correspondent, Shpital'nyy stated that future airports will be located in the immediate vicinity of large cities. No long runways will be necessary, since these will be made obsolete by VTOL planes, helicopters, JATO, and catapults. Leading Soviet designers, including O. K. Antonov, N. I. Kamov, and A. N. Rafaeilyants, have approached the problem with great resources of skill and ingenuity. The application of plasma promises a manifold increase in the present engine efficiency, and theoretical studies in this area are being pursued by a team of Soviet physicists, mathematicians, and mechanical engineers. Their

task is particularly difficult since very little information regarding plasma application has been available so far [14].

A question uppermost in the minds of world air-transport planners and operators at this time is whether the supersonic transport is economically feasible. The answer to this question is given by N. Aleksandrov in an article titled "Communication Channels of the Fifth Ocean" [15]. Further advances in aviation, writes Aleksandrov, are closely related to increased reliability, comfort, speed, and economy, the latter two being interrelated. At cruising speeds of 1000—1300 km/hr, as a result of increased air resistance, jet engines use a large amount of fuel and render jet-aircraft operation uneconomical. The situation changes radically as soon as the aircraft crosses the sound barrier. Subsequent increases in flying speed entail a reduction in operating costs. Tests indicate that the best-performing long-range aircraft would be a supersonic turbojet airliner flying at speeds of 2500—3000 km/hr. It should be borne in mind that economical subsonic turboprop and turbojet aircraft will continue to be used on short routes. Of these, the most practicable would be VTOL vehicles with swiveling wings and powerplants. However, transcontinental routes will be served by rocket planes as well as by supersonic jet airplanes.

Aleksandrov suggests the following criterion for the economic efficiency of transport aircraft: An airplane flying at 1000 km/hr and carrying a load over a distance of 15,000 km will expend 15 million kg-m of energy for each kilogram of load. When the same load is carried by a rocket plane, energy will be expended mainly to lift the load to a certain altitude and to impart to it the necessary velocity, after which the engines will shut off and the rocket will be propelled by its kinetic energy. We know, Aleksandrov continues, that 200,000 kg-m of energy is required to lift a 1-kg load to an altitude of 200 km. The energy needed to provide this load with near-orbital velocity is equal to 3.2 million kg-m. The rocket aircraft is expected to be four times as economical as the subsonic airplane and will fly 20—25 times faster.

Leonid Selyakov, chief of the A. N. Tupolev Design Office, has stated that this office is working on a passenger version of an aircraft similar to the British VC-10 and DH Trident (with engines in the rear of the fuselage), and that the USSR expects to be the first to develop a supersonic passenger airliner [16]. This airliner should be completed in the late sixties.

SECTION III. THE VOSKHOD SPACECRAFT

The Voskhod is said to represent a substantial advance in Soviet space technology, particularly in the field of space medicine. Although the Russians as usual disclosed few details of their spacecraft, several noteworthy innovations were claimed. It is generally agreed that the Voskhod flight conformed to plan, and that it was not recalled from space because of any inadequacy in its orbit or equipment.

The three members of the Voskhod crew each published an article in the December issue of the Soviet Air Force magazine, *Aviatsiya i kosmonavtika*.

Konstantin P. Feoktistov, scientist-engineer, stated that the Voskhod spacecraft was designed to utilize the latest advances in electronics, mechanics, physics, aerodynamics, rocket engineering, medicine, and other related sciences [17]. How does it compare with its predecessor, the Vostok-type spacecraft? The author points to the following innovations embodied in the Voskhod spacecraft: 1) The Voskhod was equipped with two retrorocket units (a main and a spare) which allowed it to reach a high orbit. The Vostok spacecraft were launched into lower orbits with a maximum life of about 10 days and were to be slowed down by the friction of the Earth's upper atmosphere. The installation of a spare retrorocket allowed Voskhod to leave this "natural braking" orbit and achieve a higher orbit; 2) A new orientation system installed aboard the Voskhod spacecraft employed ion engines in controlling the direction of the spaceship's velocity vector; 3) The Voskhod was provided with a soft landing system. Two ultrashort-wave radiotelephone channels, two short-wave radiotelephone channels, one CW channel, and one special short- and medium-wave receiver were used in maintaining radio communications with ground stations; 4) A new television system allowed pictures as well as messages to be sent from the cabin. The new TV concept was also used to observe the surrounding space as seen from the instrument and retroengine section. This section was later jettisoned as the spacecraft descended and could be spotted through the portholes as it flew alongside the spacecraft; 5) Other innovations were used in radar and radiotelemetry.

In an interview given several weeks later, Feoktistov [18] listed the following as important objectives of space flight: 1) rendezvous and assembly of equipment in space; 2) the acquisition of equipment to land man on the moon and ensure his return to Earth; and 3) the analysis of possibilities and the development of systems for landing expeditions on Venus and Mars. All of the above will require new launching systems and essentially new engines.

B. Yegorov, Captain of the Medical Services [19], stated that the flight program included the following objectives: 1) study of the function of the central nervous system and the proficiency of the crew; 2) study of the effect of spaceflight conditions on the cardiovascular and circulatory systems; 3) investigation of the problems of external respiration, gas ex-

change, and energy consumption under weightless conditions; 4) study of the function of analyzers during weightlessness; 5) evaluation of the efficiency of life support and landing systems.

According to Col. Vladimir M. Komarov, pilot and commander, the main objectives of the Soviet space exploit were [20]: 1) testing the design and performance of the new multipassenger piloted spacecraft, its systems and equipment; 2) investigation of the proficiency of, and cooperation among, astronauts belonging to different professions; 3) conduct of physico-engineering and medicobiological studies during prolonged space flight; 4) continued study of the effect of various space-flight elements on the human body.

Komarov claimed that Voskhod was orbited by a "powerful new launch vehicle." According to H. Mielke, Vice President of the German Astronautical Society [21], the Voskhod inaugurated a new stage in the development of astronautics. The equipment and design of the craft were planned for prolonged astronautical missions. Soviet space specialists are said to now have the prototype of the craft that will definitely be used in future moon flights. [21]

The Russians claim to have developed a retroengine system to cushion the touchdown of the spacecraft. Presumably, this is tied into the spacecraft's attitude-control system, since to be fully effective it must eliminate lateral as well as vertical shocks. On this, Mielke writes that, "The absolutely soft landing was accomplished both by engine firing and by using specially designed parachutes. The spacecraft is first brought into the denser layers of the Earth's atmosphere by means of braking parachutes and other aerodynamic deceleration devices. Then, instead of a conventional parachute, a 'Rogallo wing' chute is deployed which, in addition to facilitating a very soft landing, also helps in guidance."

An article published recently in the East German magazine *Aerosport* predicts longer Voskhod flights and the eventual rendezvous of multipassenger craft [22]. The author of this article estimates that the spacecraft must have had at least twice the mass of the earlier Vostok vehicles, which have been estimated at 4.7 tons. The fact that the Voskhod was designated a maneuverable vehicle indicates that, like the Polet craft, it could have executed changes in its orbital parameters. Even though Commander Komarov reported that no orbital corrections were made in this first flight, there are indications that one was made after the launch vehicle had assumed an orbit very different from that of the spacecraft. Due to its powerful launch vehicle, larger size, environmental-control system, new landing system, and maneuverability, the Voskhod is considered by the author to represent an important qualitative as well as a quantitative advance in astronautics.

The new craft's cabin was apparently reenforced to such an extent that its hermetic integrity would have been preserved even in the event of a meteor impact. Commenting on attitude control and maneuverability, the author notes that the astronauts were able to stabilize the spaceship in

any direction in its orbit in order to make astronomical observations. In addition, the Voskhod can be maneuvered shortly before landing and can search out the most favorable landing site within a given area.

For psychological as well as technical reasons, future prolonged space flights will be made with crews consisting of specialists in various fields. The author concludes, "One can be sure that this first Voskhod flight will be followed by longer flights in the near future.... One can also be sure that in the not too distant future a completely successful rendezvous of this new type of multipassenger spacecraft will be achieved."

Among the planned astronomical-research projects to be carried out aboard future Voskhod spacecraft, Prof. B. V. Kukarkin [23] mentions the following: 1) photographic observations of a relatively large celestial region using a special optical system, aimed at determining short-wave radiation sources and gaining more knowledge on certain problems in astrophysics; 2) electrophotometric measurements of the most interesting stars in a broad wave range; 3) spectral study of Venus, Mars, and other planets; 4) photometry of the zodiacal light and outer corona; 5) investigation of the sky region at the Earth's libration points to determine the existence of the dust condensations reported by the Polish astronomer K. Kardelewski.

SECTION IV. SOVIET EXPLORATION OF THE MOON

During recent years the Soviet Union has built a firm foundation for accomplishing long-range space missions, and the time can now be foreseen when the Soviets will have the capability for manned exploration of the lunar surface. Although several years may pass before they can send a man to the Moon and bring him back safely, there are definite indications that an elaborate Soviet manned moon-exploration program comparable to our Apollo effort exists.

The flight of an automatic space station or manned spacecraft to the Moon appears impossible unless these vehicles are able to maneuver along the flight trajectory and in the vicinity of the Moon [24]. Consequently, Soviet spacecraft pilots will have the capability to navigate in space and to select an appropriate landing site.

As stated by V. Sharonov [25], Soviet astronomers have gained valuable information on the fine structure of the upper lunar crust, i.e., micro-topographic detail beyond the limit of telescopic resolution, from the interpretation of photometric, polarimetric, infrared, microwave, and radar observations.

Photometric data obtained from Lunik-3 showed that on the lunar surface there are no areas with a reflecting power greater than 0.29 or lower than 0.03, the latter figure referring to the darkest region of the far side of the Moon (the Tsiolkovskiy Cirque) [24].

Polarization of moonlight as a function of phase angle (the Barabashev-Markov effect) has shown that no less than 70% of the features of the lunar surface are positioned at very large angles to the horizontal plane, and that no more than 30% are perpendicular to the plumb line. This would seem to indicate, among other things, an extremely rugged lunar surface. Polarization curves for different lunar phases vary but slightly from similar curves obtained in the laboratory for powdered materials. Temperature measurements of the Moon, covering areas not less than 50 km in diameter, have yielded information about the thermal properties of the near-surface material. Thermoelectric measurements in a wavelength of the order of 8μ have made the determination of the physical properties of lunar regions 6 km in diameter possible.

M. F. Rebrov and G. S. Khozin [26] have stated that on the basis of what Soviet scientists have learned in the past few years, it can be positively stated that lunar matter resembles neither tuff nor slag in its chemical composition; it comes closest to granite, diorite, liparite, gabbro, and nephelinitic selenite. Assuming that the first Moon-bound astronauts would land near the center of the lunar disc, Rebrov and Khozin suggest that a radiotelescope be dropped in that region. This radiotelescope would have a 1-km-long wire antenna capable of receiving low-frequency radiation from all directions.

Through differences in albedo and topography, many different features can be distinguished on the lunar surface. The low albedo of lunar features has induced a school of the Leningrad University to advance the meteor-slag theory, involving the continuous effect of meteorites upon the lunar crust, and to offer conjectures about the characteristics of the Moon's upper layer to a depth of several millimeters. Professor Markov definitely rules out the possibility of any large part of the surface being covered by deep dust layers or bare rock.

An analysis of thermoelectric measurements of the temperature and heat conductivity of the outer layer of the lunar crust, and a comparison of the obtained results with the heat conductivity of telluric powders in a 5×10^{-4} vacuum, have yielded information on the nature of the near-surface material. It was inferred from these studies that the uppermost layer of the Moon is about 5-cm thick and consists of 1-mm or smaller grain. By 1960, Prof. V. S. Troitskiy has shown that the density of this lunar "soil" layer amounts to approximately 0.5 [24].

The study of radiowaves reflected from the Moon's surface yields information on the average structures of the surface with dimensions of the order of the wavelengths of the waves involved. Studies reported by Markov, carried out with 70-cm radiowaves, indicate that except for the floor and the arches of the bright cirques these waves bounce off the entire lunar surface the same as they would from a rather deep layer of dust or porous rock. On the contrary, radiowaves reflected from bright Tycho-type craters indicate that these regions consist of hard rock (having a density of the order of 2.0) covered by a white dust layer.

The fact that the floors of radiant craters can actually have such a structure was confirmed by temperature measurements made during full eclipses of the Moon. When regions surrounding the Tycho-type craters cooled from 120°C to -90°C , the temperature in the crater itself dropped to only -40°C . This difference in temperature may be ascribed to the fact that a thin layer of finely divided granular material in the crater (a few millimeters thick) overlies rock denser than that found in the surrounding area.

There is widespread belief that the Moon is surrounded by a very thin atomic-hydrogen atmospheric layer, a by-product of the "solar wind" [26]. Future Moon-bound astronauts will use special equipment to shed light on the nature of the lunar atmosphere and provide clues to the existence of volcanic and seismic phenomena on the Moon.

In Prof. Markov's view [24], the latest hypsometric maps of the visible lunar hemisphere suggest that the most suitable landing site would be one of the lunar "seas."

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